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FUNDAMENTAL PROBLEMS IN HIGH ALTITUDE AERODYNAMICS.(U)
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FUNDAMENTAL PROBLEMS IN HIGH ALTITUDE AERODYNAMICS

FINAL REPORT

October 1, 1971 to September 30, 1976

Grant No. AFOSR-72-2169

by

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I. Introduction

During the contracting period for AFOSR-72-2169, four major lines of research have been followed. Early in the period a significant effort was expended on measuring molecular velocity distribution functions in shock waves. This work has been completed and the work published (Refs. 5 & 6). Very significant results were obtained leading to a quantitative comparison of various computation methods and experiment.

Another research effort was in measuring the rotational transitions excited in nitrogen - rare gas collisions. This work has been published in Refs. 2, 7, and 8.

A third research effort, which continues through to the present, is the study of the interactions between an underexpanded gas plume and a background gas. This work is described in Refs. 1, 3, 9, 10 and 11. A fairly comprehensive understanding of the rarefaction of the interaction of exhaust plumes with their environment has resulted from this work.

A fourth research direction is the continuing study of the electron beam flourescence technique. This work is described in Refs. 8, 12 and 13. Also, the extension of the technique to measure detailed properties of high vibrational temperature, low rotational temperature flows is the subject of two ongoing Ph. D. dissertations. This work has not yet resulted in any significant publications. It is described in more detail in the main body of this final report.

II. Review of Current Investigation That Has Yet to be Completed

The expansion of vibrationally hot carbon monoxide and nitrogen to very low rotational temperatures, such as occurs in exhaust plume expansions, is of interest for exhaust plume radiation and in gas dynamic lasers.

We have, over the past several years, extended the electron beam fluorescence technique to the measurement of vibrational level population distributions in nitrogen up to the 5th vibrational level. This study has been done in the apparatus shown in Fig. 1. As illustrated in the figure, a flow through gas discharge is used to raise the vibrational "temperature" of the nitrogen. The gas subsequently expands through an orifice into a large vacuum chamber.

The vibrational population distribution of the nitrogen has been measured for various gas discharge conditions using the electron beam fluorescence technique. Initially it was necessary to do an exhaustive study of the measurement of vibrational population distributions using the fluorescence technique. This work, plus the use of the technique to diagnose vibrationally excited gas flows, is the subject of Mr. David Campbell's Ph. D. dissertation. It is currently being written.

An example of the results that have obtained to date is shown in Fig. 2. Here, the population distribution in a nitrogen flow is shown as a function of the gas discharge current. The measurements are currently being extended to a mixture of nitrogen and carbon monoxide.

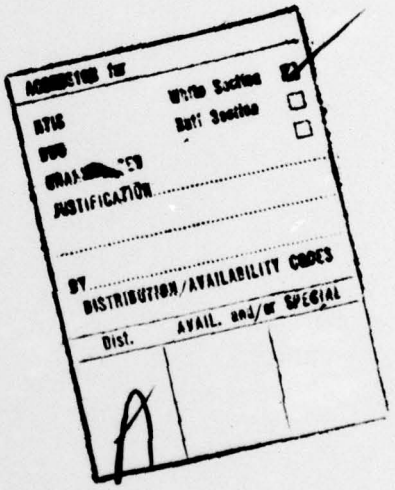
In addition to the vibrational level population distribution, the rotational temperature is of interest. We have applied the electron beam fluorescence technique to the measurement of rotational temperatures in carbon monoxide (it has already been developed to nitrogen). Rotational temperature is important, particularly in gas dynamic laser applications where the inversions are generally partial inversions. This can be seen from the calculated inversion densities shown in Fig. 3. The calculation indicate that a maximum partial inversion occur at quite low rotational temperature (15 - 20^{o} K) for carbon monoxide at typical vibrational temperatures. Operation at very low rotational temperature permits one to consider low vibrational level lasing transitions for relatively modest

vibrational temperatures (e.g. Fig. 3). Rotational temperature measurements in carbon monoxide is the subject of Mr. A. Powell's Ph. D. dissertation.

III. Professional Activites and Publications

Publications associated with this grant are listed in the accompanying publications list.

The pricipal investigator has, during the contracted period, participated in consulting activities with: Grumman Aerospace, Aerospace Corporation and L.T.V. on problems generally associated with the work being done on this grant. The principal investigator was also co-chairman of the 10th International Symposium on Rarefied Gas Dynamics, held in 1976 at Snowmass, Colorado.



Publications

1. "A Study of Background Penetration into Underexpanded Jets and the Resulting Separation of Gas Mixtures." E.P. Muntz, B.B. Hamel and P.B. Scott, Entropie, 42, 28, 1971.

2. "Rotational Transition by Nitrogen in Rare-Gas Collision." P.B. Scott and T.R. Mincer, Entropie, 42, Nov.-Dec., 1971.

3. "Simulation of the Interaction of High Altitude Plumes and High-Speed Free-Stream Flow." T. Holtz, E.P. Muntz, AIAA Preprint No. 72-1019 Sept. 12-15, 1972.

4. "On the Reattachment of a Shock Layer Produced by an Instantaneous Energy Release." H.K. Cheng, J.W. Kirsch and R.S. Lee, JFM, 48, pt. 2, pp. 241, 1971.

5. "Experimental Investigation of Normal Shock Wave Velocity Distribution Functions in Mixtures of Argon and Helium." L.N. Harnett and E.P. Muntz, Phys. Fl., 15, No. 4, pp. 565, 1972.

6. "Measurements of Molecular Velocity Distribution Functions in an Argon Normal Shock Wave at Mach Number 7." Jan. 1974, (Ph. D. dissertation, Univ. So. California). Also "Comparison Measured and Calculated Molecular Velocity Distribution Functions in a High Mach Number Shock Wave". T. Holtz, et al, A.P.S. Bulletin, Series 11, Vol. 18, pp. 1476, Nov. 1973.

7. "Nitrogen Rotational Excitation by Collisions with Argon-Observation and Comparison with Theory." P.B. Scott, et al, Chem. Phys. Letters, p. 71, Sept. 1973.

8. "The Electron Beam Fluorescence Method as Applied to Molecular Scattering Experiments." P.B. Scott, et al, Rev. Sci. Instruments, Vol. 45, No. 2, pp. 207, 1974.

9. "A Study of the Rarefaction of the Interaction Between an Exhaust Plume and a Hypersonic External Flow." F.K. Mc Ginnis, et al, AIAA Paper No. 73-199, Washington, Jan. 1973.

10. "Rarefaction Phenomena in Gas and Isotope Separation." E.P. Muntz and B.B. Hamel. Preceedings of Ninth International Symposium on Rarefied Gas Dynamics, Gottingen, 1974.

11. "Aerodynamic Separation of Gases and Isotope." E.P. Muntz and J.F. Wendt, V.K.I. short course, Jan. 1976, to be published as a V.K.I. Monograph.

12. "Density Measurement Using the Electron Beam Fluorescence Technique." Section in Methods of Experimental Physics-Fluid Mechanics, ed. R.J. Emrich, to be published, 1977.

13. "Temperature Measurement Using the Electron Beam Fluorescence Technique." Section on Methods of Experimental Physics-Fluid Mechanics, ed. R.J. Emrich, to be published, 1977.

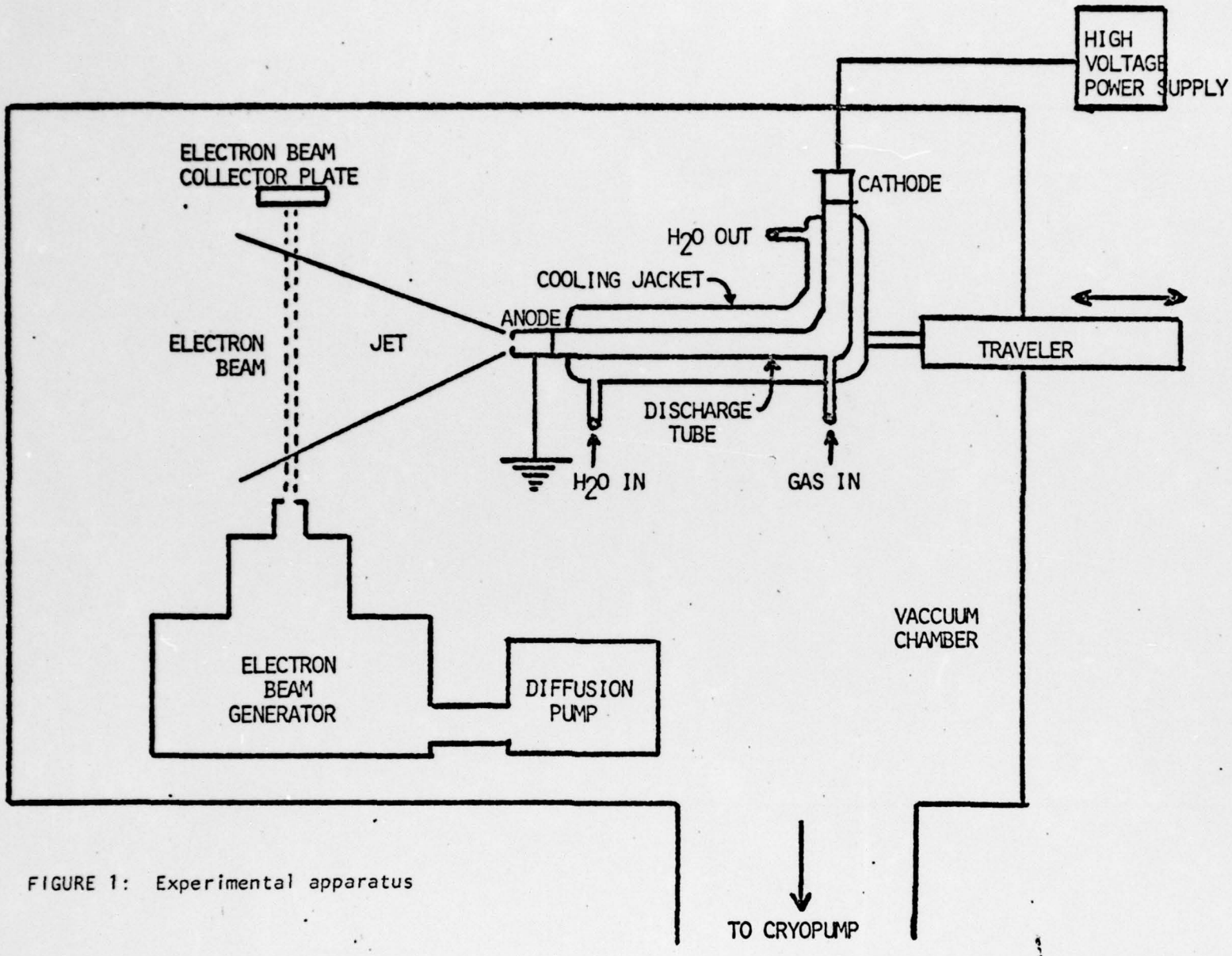


FIGURE 1: Experimental apparatus

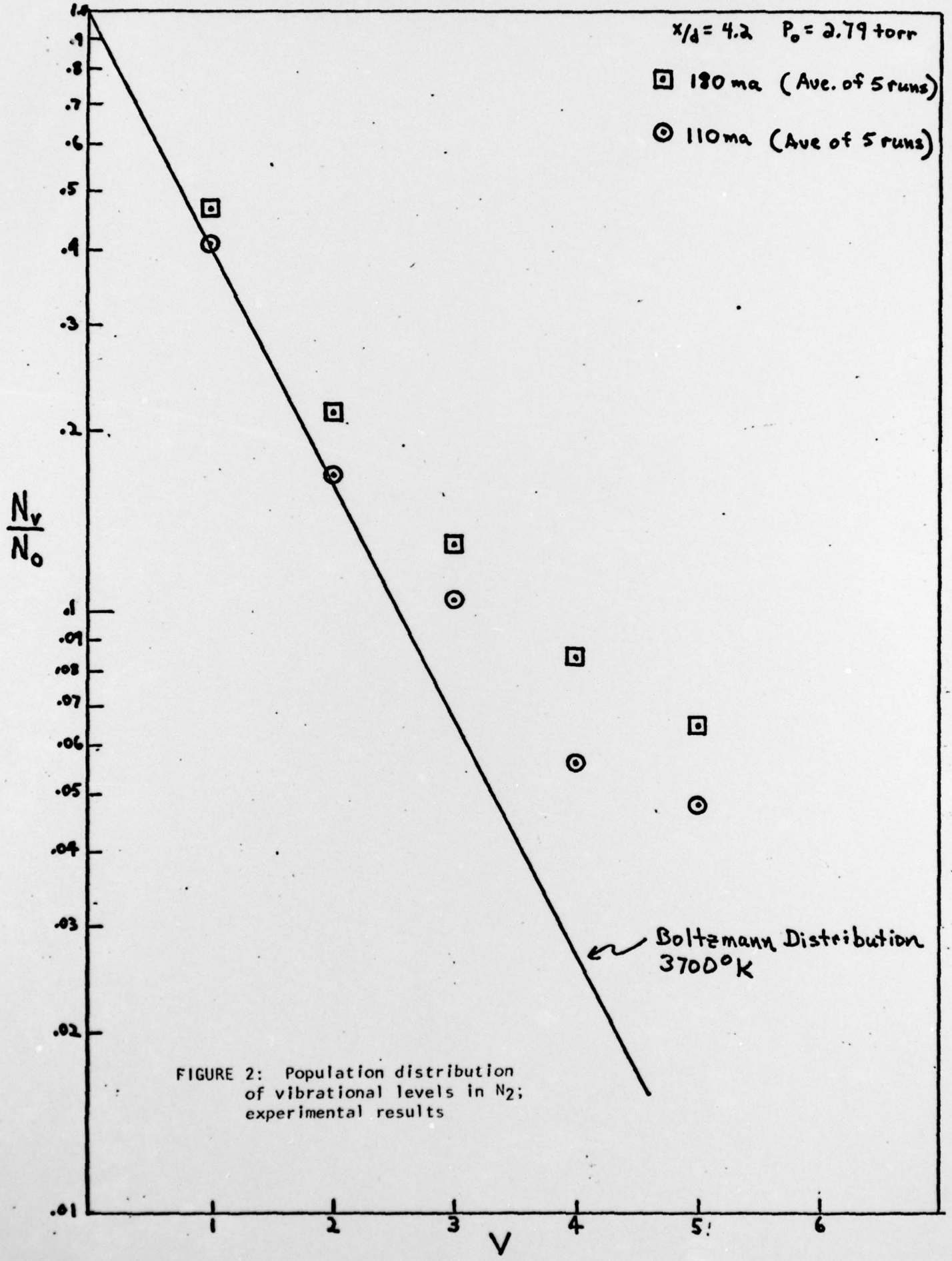


FIGURE 2: Population distribution of vibrational levels in N_2; experimental results

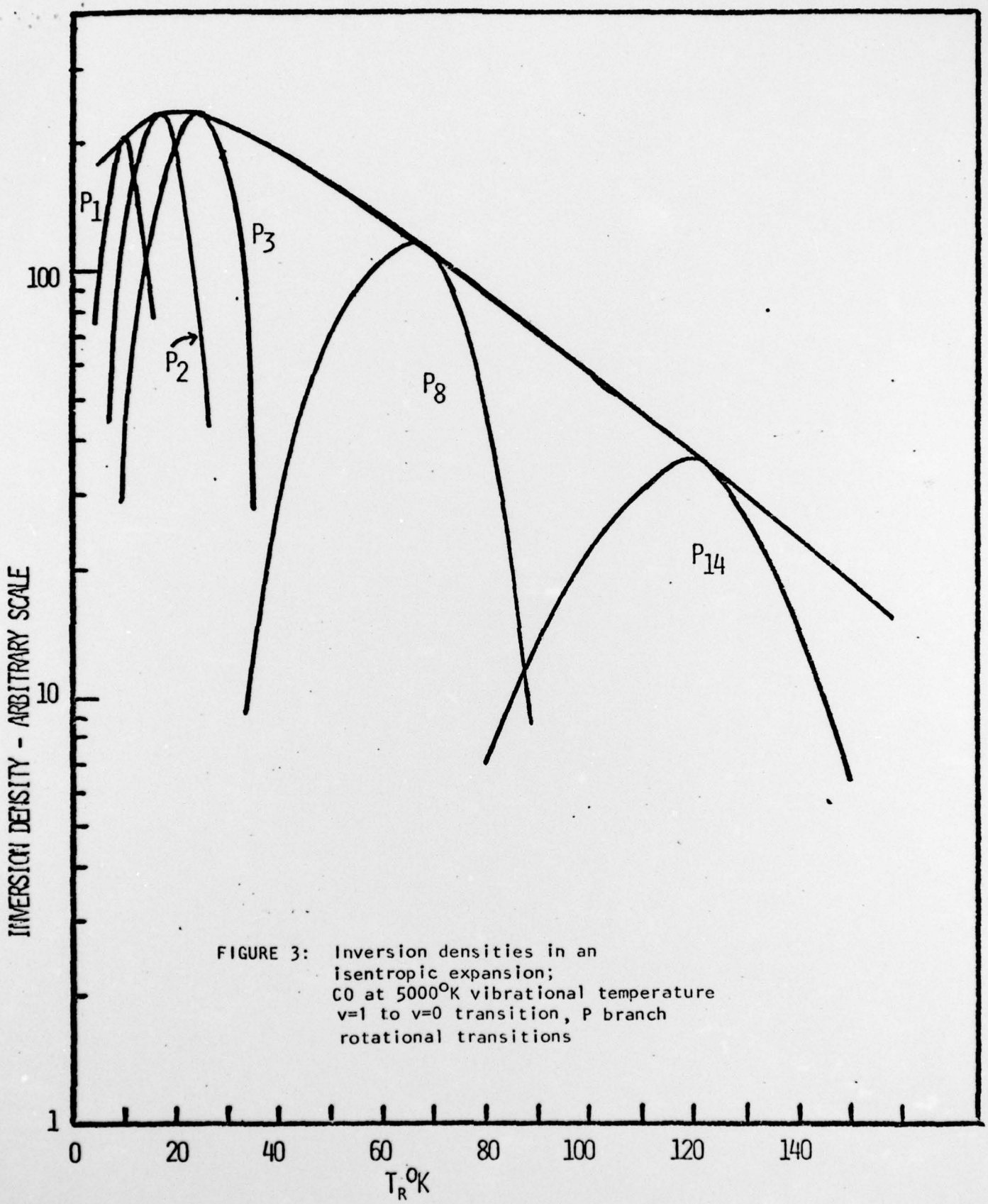


FIGURE 3: Inversion densities in an isentropic expansion; CO at 5000°K vibrational temperature v=1 to v=0 transition, P branch rotational transitions

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